International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 3, March 2017, pp. 853–867 Article ID: IJCIET_08_03_086
Available online at http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=3
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

THE INTEGRATION OF CLIMATE RESPONSIVE DESIGN AND TRADITIONAL SETTLEMENT IN HIGH ALTITUDE-A CASE STUDY OF SPITI VALLEY

AR. Snigdha Chaudhary
Assistant Professor, Architecture Department,
Amity School of Architecture and Planning, Noida, India

ABSTRACT

Traditional architecture takes into account the styles that were popular to a region or area. The characteristics of traditional architecture used by architects and builders includes a commitment to maintaining a link to the past styles of building, reuse of materials or designing homes and building to stay consistent with the overall building design of the area. This creates a sense of continuity and connection to the past, which helps the area maintains its traditional look and feel for the residents of the community. In the traditional architecture, buildings were designed to achieve human comfort by using locally available building materials and construction technology which were more responsive to their climatic and geographic condition. This paper will try to bring out the wisdom of the local masons and builders, often the inhabitants themselves, about their way of living, and shaping their built environment, indoor and outdoor spaces, as a response to the local climatic conditions, from the findings of a field study at a hilly settlement in Spiti.

Key words: Traditional architecture, High altitude, Climatic adaptation, Sustainable construction.

Cite this Article: AR. Snigdha Chaudhary, The Integration of Climate Responsive Design and Traditional Settlement in High Altitude-A Case Study of Spiti Valley. *International Journal of Civil Engineering and Technology*, 8(3), 2017, pp. 853–867.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=3

1. INTRODUCTION

Through the advancement achieved in the field of building science and technology, we are increasingly becoming aware of the importance of the energy-efficient building design.

- Many a times one can find the solution to optimize the use of resources and to achieve the human comfort by critically evaluating the vernacular architecture of that place.
- Inhabitants often employ and use various adaptive features in their houses to keep the indoor conditions within comfortable zone.

- The best way to understand the architectural characteristics of a settlement is by conducting field survey/study. During the physical on-site survey of the settlement, individual automatically starts gaining knowledge about the process of shaping their built-environment, evolution of the building typologies and their adaptation with change in their need.
- The following study was conducted to gain knowledge and wisdom from the local masons and builders, often the inhabitants themselves, about their way of living, and shaping their built environment indoor and outdoor spaces, as a response to the local climatic conditions.

2. OBJECTIVE OF THE STUDY

Following were the objectives of the study of a high altitude settlement in Spiti :

- To find out the morphological growth pattern of the settlement,
- To understand the architectural planning pattern of the settlement,
- To analyse the architectural design of the individual dwelling units as manifestation of various design parameters, such as local climate conditions.
- To find out the architectural details of various buildings elements, motifs, symbols, etc., used by them to build our design vocabulary.

3. DESCRIPTION OF THE SETTLEMENT

The aim was to find out the salient architectural features of a high altitude settlement. For that a traditional settlement in the hilly region of Spiti Valley at Himachal Pradesh was selected. The settlement pattern in Spiti is mainly dispersed. Most of the settlements in this region are on the sun facing side and the houses are located on the south facing slope of mountains. All the settlements in the entire Spiti valley are wet point settlements. In this region, water is a scarce resource and since agriculture is the mainstay of economy, water is required for cultivation. Most villages are therefore located along or near the *nallah* sides. Some villages are situated on rolling highland pastures as well, near some glacier fed stream. Proximity to the water source for meeting the daily needs as well as for irrigation seems to be the chief consideration although availability of construction material, the existence of sizable plots of land for agriculture and ample grazing area for the cattle, have played a dominant role in the selection of sites. Based on the location with respect to the river the target region can be categorised under three distinct types of settlements.

- **Basins**: These settlements are located at river basins, at a height of about 20-50m above the basin. The basins are either spread on one side of the river or on both the banks. These are essentially flat tracts of lands but at a few places are also in the form of moderately sloped terraces. The banks are not too steep and water for irrigation can therefore be drawn directly from the river with the help of diversion channels, for eg., in Tabo in Spiti or in Jispa in Lahaul.
- **Steep Banks**: In the middle regions of the valleys, steep cut banks separate the villages from the river. Settlements are located at about 50-100mheight above the river level. These villages depend on glacial melt for both drinking and irrigation needs, for eg., Kaza in Spiti, Khoksar in Lahaul. These differ from the basin settlements essentially due to the fact that they are located considerably above the river basin. Hence water needs are supplemented primarily by the natural springs and glacial melt.
- **Highlands:** These include the highest settlements of the valley, more than half a kilometer above the river bed. Flat tracts of land on high mountains are the typical features of these kinds of settlements, although at places terraced fields also exist on moderately sloped hill faces. The river is completely inaccessible from these places. These settlements therefore have

to depend solely on snowmelt for meeting their water requirements, for eg., Kibber in Spiti, Rashal & Gondla in Lahaul.

In all there are 113 settlements in Spiti, 32 of which are listed as uninhabited. Spread over 81 villages, 2,425 house holds average 30 households to each village. Actually, however, there are as many as 33 villages which have ten or less number of houses, and only a few have a large cluster of houses.

Some of the important villages - there are no towns - of Spiti are:

- Kaza, the headquarters of the Additional Deputy Commissioner of Spiti,
- Rangrik,
- Dhankhar, the traditional capital;
- Lalung,
- Hikkim,
- Kee,
- Kungri,
- Tabo, well known because it houses the world famous, nearly 1000 year old, Tabo monastery;
- Kaurik, yet another gate-way to Tibet;
- Kibber perched high at 4000m on rolling bare mountain top;
- Gue, the highest point in a side valley and
- Gette, pride of Spiti, situated at a height of 4,270m, the highest inhabited village in the world.

There are also seasonal settlements characterized by hardly one or two single room buildings. These summer settlements are surrounded by the small landholdings and the pasturelands usually located on the higher reaches; locally these summer settlements are called Doghris.

The layout of the villages is neither uniform nor does it answer to any planning concept (see photo-1). The villages in Spiti have some common characteristic features like chorten, tagoh, baraghar (Khang Chen) and a gompa. It is not essential for all villages to have a gompa; three to four villages may also share one common gompa. Generally the houses are built separate. Often their growth is haphazard and congested. They are built just anywhere in the village so that it is often difficult to find a path between them. The lanes or by-lanes are narrow and drainage is unknown.

Figure 1 A View of Settlement near Dhankhar village, Spiti Valley

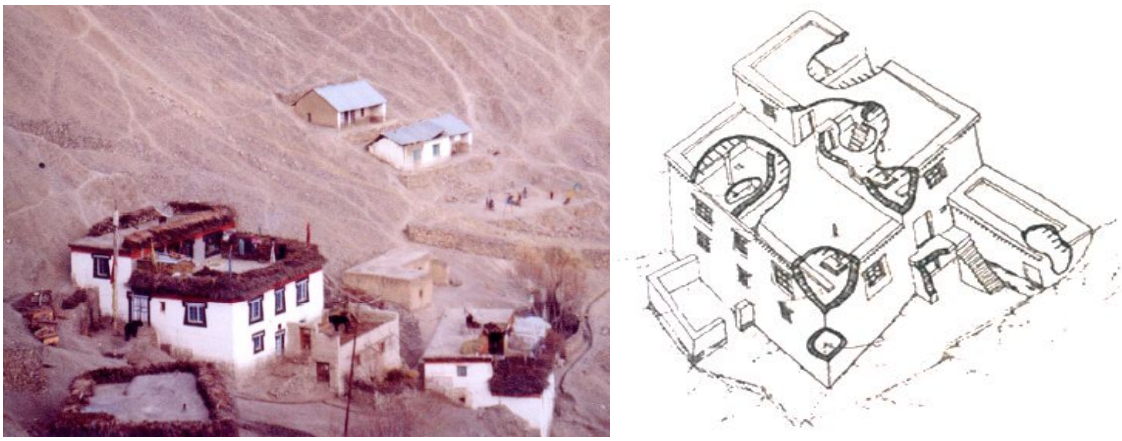

Figure 2 A typical Spitian house in Dhankhar village

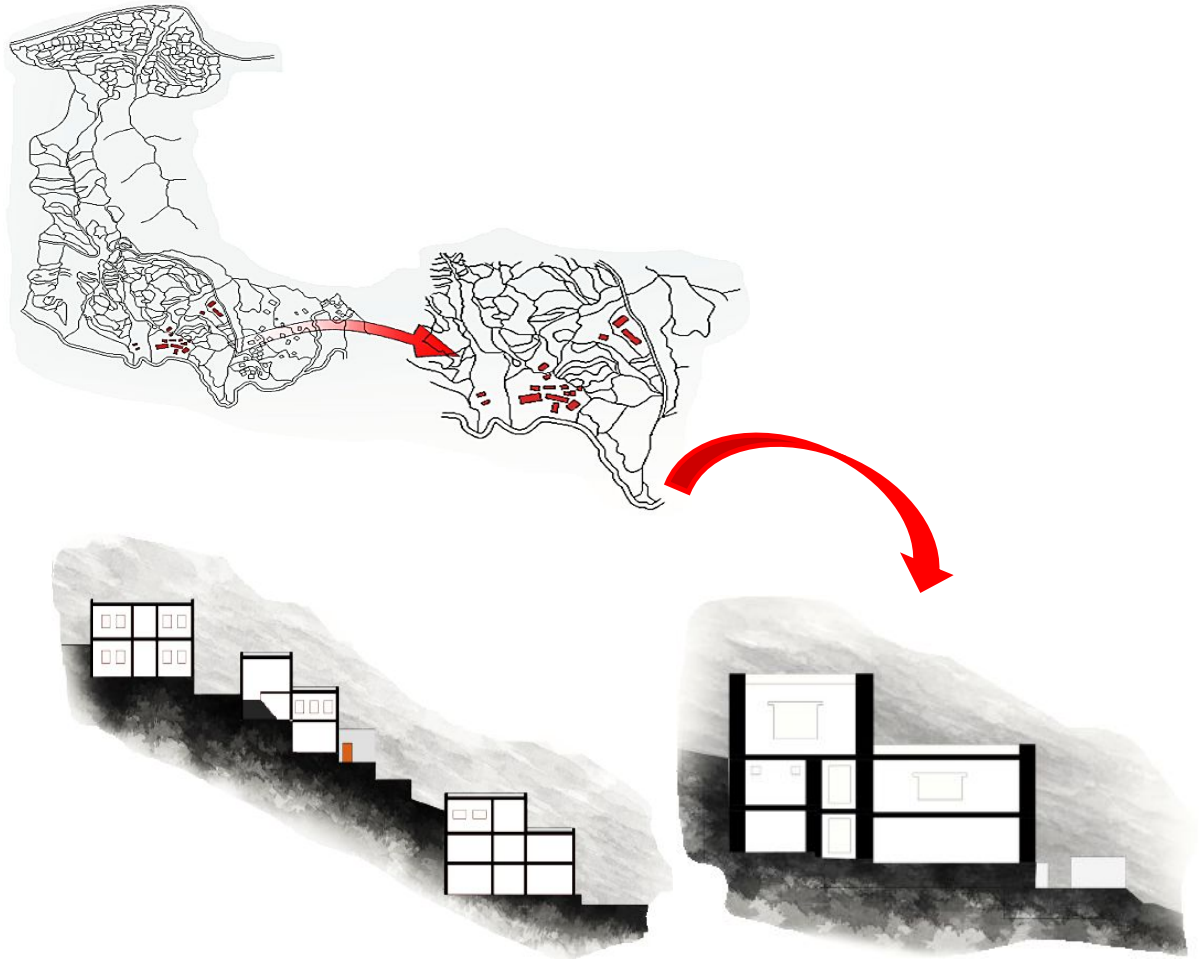

Figure 3 Shows Settlement near Dhankar village, Spiti Valley

The terrain divides Dhankar Village into two parts:

1. Upper Cluster,
2. Lower Cluster

- The growth of the houses is organic and along the stepped terrain.
- The main village street runs in the north south direction. It links the

1. Palace,
2. Lower Cluster,
3. Upper Cluster,
4. Monastery

The living room and the kitchen are on the upper part.

The south sun makes the low temperatures bearable thus the main living areas located on the southern side.

The kitchen is also used as a bedroom (main room) due to the warmth of the cooking stove.

There are two separate Kitchen: 1. The Upper One: Winter

2. The Lower One: Summer

The terrace can be easily accessed and is used for various activities like Weaving, Sleeping, Drying grains, etc.

4. APPROACH FOR CLIMATE DESIGN

A building designer should use / manipulate the following major design elements / tools to control the thermal environment in the buildings to suite the climatic conditions of the place:

1. Shape of the building (massing),
2. Fenestration (size, positioning and orientation of windows),
3. Building fabric (insulation & thermal storage),
4. Solar control (shading & surface finishes),
5. Ventilation

5. ARCHITECTURAL FEATURES OF SETTLEMENT AND DWELLINGS

- **Shape of the Building (Massing):** Traditional dwellings in the settlement are being constructed in a straight forward way based on the functional requirements of the users and the availability of the suitable building materials and construction techniques developed over the centuries to provide comfort to the users from the extreme cold. The dwellings are of two storeys high with linear arrangement of rooms, connected by verandah / balcony, in both the floors. Fig. 3 shows the typical floor plans, section, and elevation of the dwellings. Normally in the ground floor/level, cattle-shed and storage areas are provided. In the upper level, all the living areas are provided along the cooking area / kitchen; this helps in keeping the surrounding rooms warm during cool night time. Also attic space is provided below the pitched roof covered with shingles / stone tiles. All the wet areas are normally kept separate from the living areas. All the habitable rooms, verandah and balconies are oriented towards the south, east and west to receive the maximum solar heat gain during day time, which are stored in the thermal mass of the dwellings to keep the interiors warmer during night time. Mostly the height of the rooms was kept lower (2.1 - 2.4 m). This low ceiling height helps to keep the interior of the rooms warmer from the heat released by the individuals. Also this contributes to the low surface-to-volume ratio of these dwelling units and thus reducing the heat loss from its surfaces.

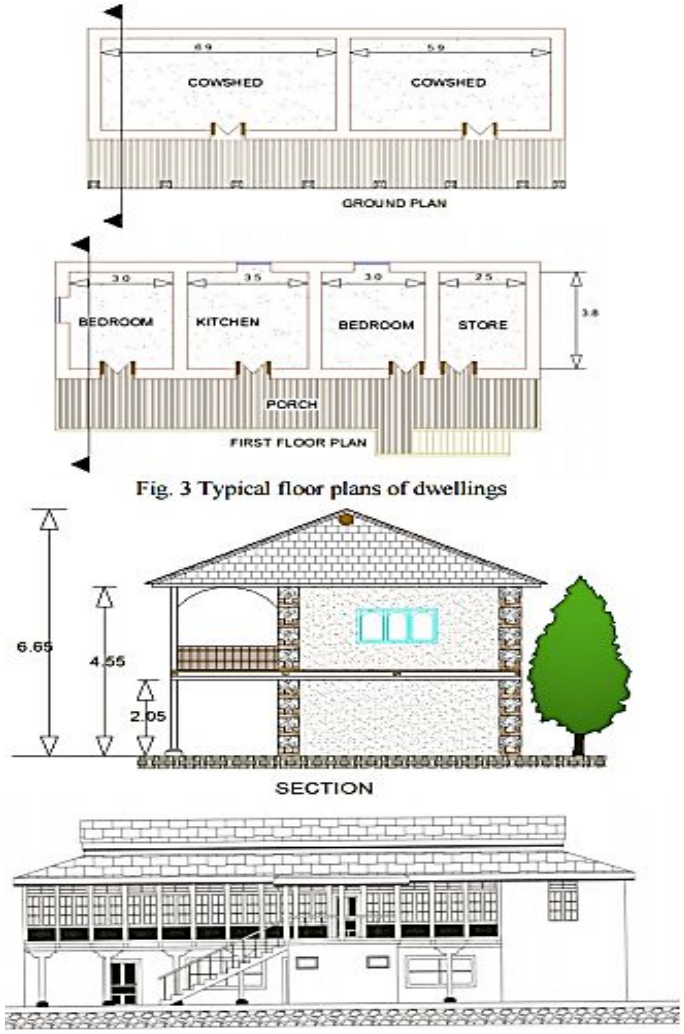

Fig. 3 Typical floor plans of dwellings

Figure 4 Typical Floor Plans of dwellings

- **Fenestration - Size, Positioning and Orientation of Windows**: Small size openings are provided in the rooms of the dwellings with operable timber and glass shutters. Openings were mostly provided on east, west and southern walls. Rooms were single-loaded and connected by timber verandah / balcony. These verandahs are also provided with continuous operable timber and glass shutters, to allow sunlight to come inside the dwellings when open and are kept closed during night-time and winter time, when there are chilled air blowing, to prevent heat loss. The openings at the ground level are protected by the balcony above, and the openings at the first floor are protected by the projection of the pitched roof. No openings are provided in the northern side to avoid the cool winter air. These features also help in solar heat-gain in winter and prevent heat-loss during cooler nights.
- **Building Fabric - Insulation & Thermal Storage**: In almost all cases, the nature has provided the building materials suitable to the local climatic conditions. In this settlement also, it was found that the dwellings were constructed with locally available timber and stone materials, both having high thermal capacity and low conductivity (kvalue in W/m ºC) – for hard timber 0.16 and for sandstone 1.295.
- **Walls:** The walls are made of stone masonry and timber having thickness of 45-60 cm. This traditional style of wall construction is known as 'Kath-Khuni' or 'Dhajji-wall' construction method. This indigenous style of wood-and-stone construction technique is both practical and aesthetically pleasing. By the systematic process of layering and interlocking the locally available timber and stone materials, the construction becomes inherently strong, stable and

flexible to make them suitable to their mountainous terrain that is prone to earthquake. These heavy walls allow a very good thermal insulation by providing high time-lag of more than 8 hours. This makes the interior of the house cooler in summer and warm in winter for maximum part of the year.

- **Flooring**: In the ground level mud & cow-dung were used for flooring above the plinth made of random rubble masonry. The upper floors are made of timber planks and timber-joists, shown in fig. 6. The use of timber also prevents / reduces heat-gain and heat-loss through floors to a great extent.
- **Roofing & Rain Protection**: Pitched roofs were provided with rafters and purlins made of locally available slender timbers. Roof covering was done with slate made from locally available stones. Below the roof a ceiling was constructed with timber. The attic was normally used for storing food-grains and also as the abode of the God. The light-weight roof construction and the air between the roofing and attic-floor provided a very good thermal insulation against the passage of heat. The heat stored during the day time of the winter, helped to keep the interior warmer during cool winter nights. Fig. 7 shows the roofing pattern of dwellings in the settlement. The settlement receives sufficient amount of rainfall through the year. Hence the low pitched roof was a very good solution to drain off the rain-water from the dwellings. Also the roof-edges were sufficiently projected to protect the wall against damage from rain-water.
- **Special Features and Activities**: The dwellings are oriented for the maximum solar heat gain, a basic design approach for the buildings in cold climate. Also they have created their indigenous style of sun-space or solarium by using the balcony in the first floor. The natural contour / slope of the site were used for the drainage of rain-water. Sunny courtyards were used to perform various outdoor activities during day-time. Another salient feature observed in the dwellings is the location of the kitchen. They are located on the upper floor, the cooking space – 'chullah', normally made of mad, is placed either at the center or at one side of it. This spatial arrangement helps in keeping the indoor warm even in the cool nights.

6. BUILDING MATERIAL OF DWELLINGS

The houses in Spiti use primarily the natural renewable materials available locally, viz, mud, wood, scrub and stones, as building material for construction. The foundation of the house is usually of stone, the walls are made of mud and the ceilings are of wood, branches, scrub and mud

Based on availability, the building material may be divided into three categories:

1. **Ubiquitous**- the material which is available at all places in Spiti, e.g., scrub, mud etc.
2. **Localized**- the material which is available only at certain specific locations in Spiti, e.g. willow, clayey soil, etc.; and
3. **Rarity** - the material that is rare and difficult to source in Spiti, e.g., wooden logs, etc.

Table 1 Building materials and its usage

Local name	English Name	Availability	Usage
MakhdungKa	wooden logs of poplar (maksa)	Maney, Tabo &Kinnaur(localized)	placed horizontally over theKaje to support the ceiling
Phurdung	wooden logs of poplar (maksa)	Maney, Tabo &Kinnaur(localized)	placed over the Makhdung, it helps in the formation of the ceiling.
Thillu	stems of willow &seabuckthorn(churchung)	Lossar and Lalung (localized)	fills the voids created by theMakhdung&Phurdung
Thapp	branches of willow and scrub (penma&ombu)	(ubiquitous)	spread over the Thilluto fill the gaps in the Makhdung&Phurdung
Dhambuk	mud	(ubiquitous)	spread to plaster the empty spaces created because of the interlocking of ceiling Makhdung, Phurdung, Thillu and Thapp
Tooah	clayey soil	riverside (localized)	water resistant mud used for plastering the roof; also spread over the Dhambuk; used for plastering the outside walls.
Ka&Kaje	Wooden logs of eucalyptus	Pin valley (rarity)	placed vertical in the centre of the room to support the ceiling
Penma	scrub	(ubiquitous)	painted black for decoration and placed on the edges of the roof to protect the walls from snow
Chak	red soil	Lidang (rarity)	used for painting the wall on the upper part of the house in the form of a strip for decoration
Kirsi	limestone	(localized)	used for white-washing the building from the outside

Source: Data collected by 3rd Year B.Arch. student, Amity University 2016.

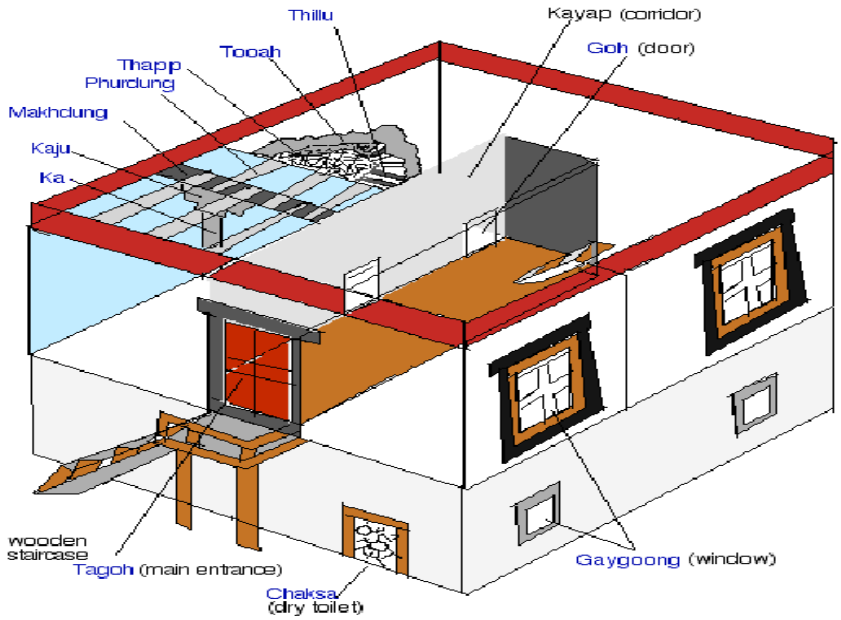

Figure 5 Shows Three Dimensional View of the Spitian House, Spiti Valley

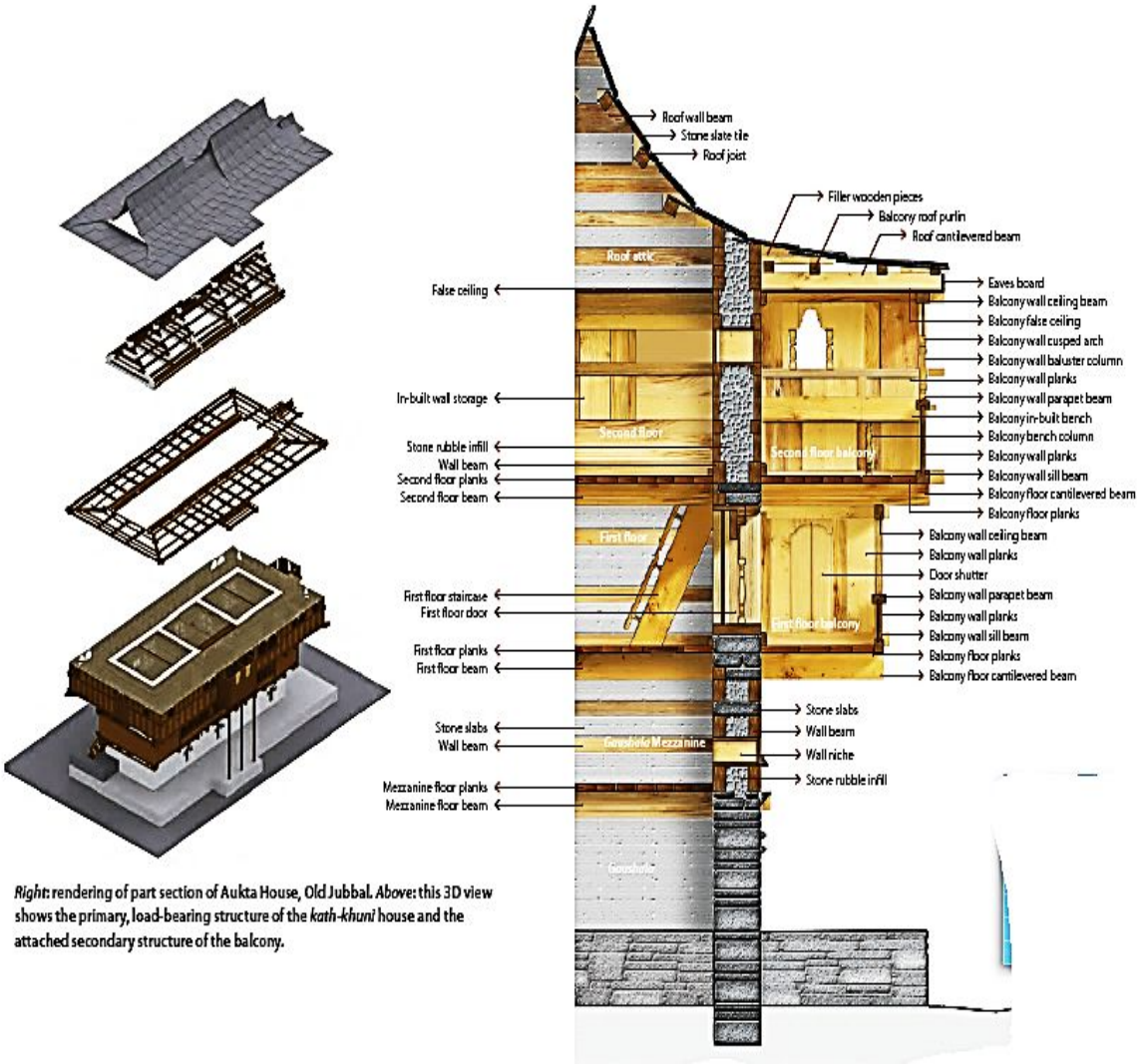

Figure 6 Shows Sectional View of the Spitian House, Spiti Valley

7. CLASSIFICATION OF CLIMATIC ZONES AND THEIR TRADITIONAL CONSTRUCTION TECHNIQUES

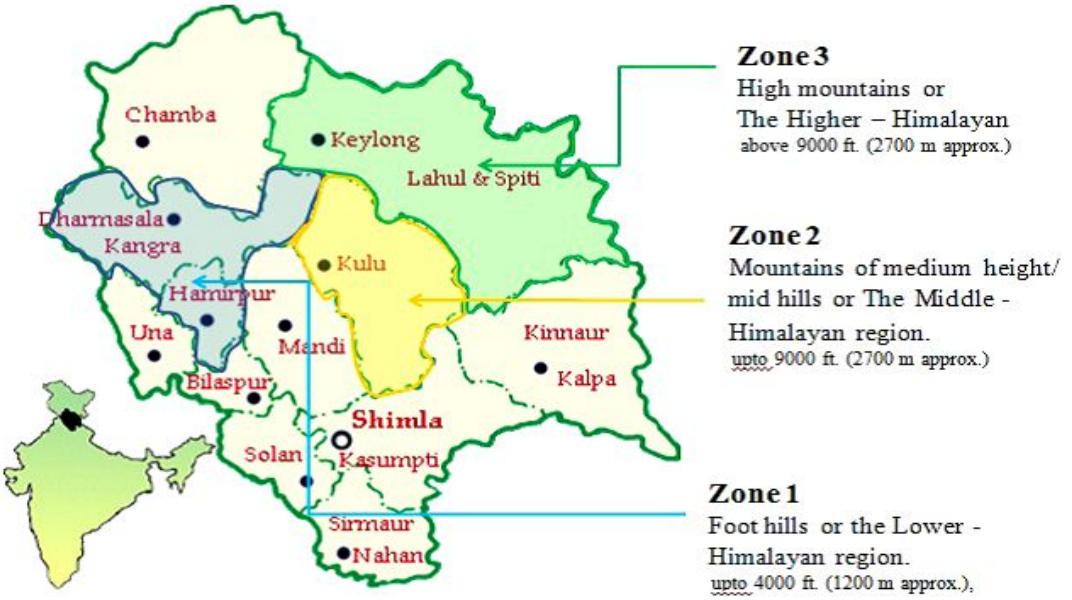

Figure 7 Map of Himachal Pradesh showing classification of zones
(Source:www.indianetzone.com/3/himachal_pradesh.htm)

The character and forms are different from one climatic and geographic zone to other which can be identified in three separate zones, i.e., upto 4000 ft. (1200 m approx.), upto 9000 ft. (2700 m approx.) and above 9000 ft. (2700 m approx.) So the state of Himachal can be broadly classified into three zones depending upon their elevations.

7.1. Foot Hills or the Lower - Himalayan Region

In the first climatic zone i.e., up to height of 4,000 ft. (1200 m approx.), where climatic conditions are mild throughout the year, i.e., pleasant summers, mild winters and medium rain falls. Flora of this region is similar to that of Tarai belt. The special characteristics of this zone are absence of snow fall. The orientation of the buildings in this zone is mostly East and South. The slope of the land is from 0 to 30 approximately. Materials available for construction are stone slabs for flooring and roofing, stone and earth for walls and wooden plank supports on wooden joists for intermediate floors. A typical innovative technique for construction of earthen walls is use of a bottomless wooden box 0.60X0.90 m, with a height of 0.23 m in which earth is filled and rammed thus creating 0.23 m layer of rammed earth at every stage for the construction of a wall which is 0.60 m thick. The another innovative techniques is the use of locally available slate stone which are used for sloping roof and are placed on heavy wooden supports with overlapping of 0.0254 - 0.0308 m. These slates are not fixed to wooden supports but remain in place by weight only or sometimes they nailed to the wooden joists/rafters. The slope of roof is confined to maximum 22.5 degree.

In areas of heavy rainfall such as Dharamshala and Palampur steeply-sloping roofs and deep verandahs are necessary, the former to drain off the rains quickly and the later to allow open-air living during rainy season and for protection of the walls. Before the British influence, the buildings constructed in these areas bore the influence of Rajasthan and Mughal architecture which existed throughout northern India at that time. However, with the coming of the British the jack-arch was introduced and Dharamshala-type roofing was evolved for areas of heavy rainfall using plain or galvanized iron sheets for roofing. tables and

figures you insert in your document are only to help you gauge the size of your paper, for the convenience of the referees, and to make it easy for you to distribute preprints.

7.1.1. Traditional Construction Techniques

7.1.1.1. Mud Construction

Mud construction is prevalent in Himachal in two types, rammed earth conduction and sun dried mud brick construction. Sun dried mud bricks are used in the Kangra region where good quality of mud is available from the river beds. The walls are made of sun dried bricks about 0.60 – 0.90 mt. thick plastered with mud phuska. These walls are susceptible to erosion due to rain thus the buildings are raised over stone or plastered to avoid erosion. The floors are made of wood plastered with mud enabling insulation

Figure 8 Views of Mud construction (a) Rammed Earth Construction (b) Staircase detail in Mud House (c) Modern House made up by traditional construction techniques (d) Interior details of mud brick house.

7.1.1.2. Dry Stone Construction

Dry stone construction is common in Kangra region where slate is in abundance (Fig.9). However this type of construction is also common in Kinnaur district where good quality stone can be quarried. Different sized stones are placed over each other and compacted without the mortar. Through stones are used at regular intervals. A stronger bond is achieved by interlocking the stone rather than adding smaller stones in gaps. Interior surface may be mud plastered. The stone masonry structural walls take main lateral and gravity load. The walls uniformly distribute the load in both orthogonal directions.

Figure 9 Views of Dry Stone construction

7.2. Mountains of Medium Height/Mid Hills or the Middle - Himalayan Region

In the second climatic zone up to 9000 ft. (2700 mt. approx.), the hills are steeper. Northern slopes of the mountains are thickly forested, while habitation is confined to Southern slopes. The climate throughout the year is mild to chilly in comparison to planes, i.e., cool in summer and rainy season with heavy rain fall. During winter there is always snow fall and temperature goes down below zero. The flora in the region consists of temperate zone species; Pine in lower altitudes and Deodar, Chilgosa and Betula in higher altitudes. The design of buildings in this zone is influenced by the elements of snow fall, chilly winter and heavy rain fall. The building materials available in inaccessible areas are stone and wood. ln this zone, most better-class houses and even poor ones are built with stone and wood, without mortar. The typical Himalayan house of this region consists of two or more stories (Fig. 8), with cattles in the ground floor, grains in the middle floor and dwelling in upper floor surrounded by a deep over hanging verandah which is used for various purposes such as living and storage of fuel wood and fodder. The typical feature of vernacular architecture in this zone is the projection of upper floor. The walls construction is done with stone and wood without mortar.

Figure 10 Cattles on the Ground floor and dwelling on First Floor also the Fenestration on south facing at Spiti

In this traditional Himalayan method of construction the wooden beams extend to the whole length of the wall, one beam on the outside and another on the inside, the space in

between filled up with stone. The wall at right angles has its beams laid on the two just mentioned and the alternate placing of these beams continue in this way. From this it will be understood that the construction is capable of holding itself together without the stones which are filled in to form a solid wall. On top of this mingling of wood and stone stands the real dwelling, which is entirely of wood. Supported by beams, it over hangs the more solid structure beneath. A row of small pieces of wood, named 'Jhallar' are hung from the upper cornice. The bells at the corner also hang loose and are moved by the wind. This type of construction is mainly found in the higher ranges of Kinnaur and Kullu districts of Himachal. The most common type of kath - kunnni wall is made by laying apart two square sectioned wooden wall beams (Fig. 9) longitudinally parallel to each other to define the width of the wall. In order to ensure the proper bond between the two these are dove-tailed or lap jointed by the cross-joists, suitably placed along the length of the wall.

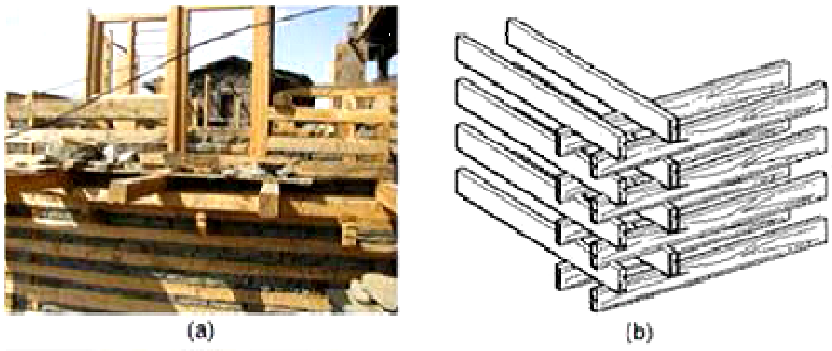

Figure 11 Views of Kath- Kunni Construction

The walls are constructed of alternate layers of wood and stone (Fig. 11). The wood battens 0.10-0.15 m thick extend beyond the wall length and interlock with the wood on perpendicular wall. The wooden planks are interlocked by lap joint. Floors are made of wood not more than 2.10-2.40 m high for better insulation. The upper floors project out of the stone wall with wooden balconies creating a sun space for sitting. Thus maximizes the heat gain. This type of construction is earthquake resistant as the wooden battens form a framework which is well bonded and gives ductility to the otherwise rigid stone wall.

7.3. High Mountains or the Higher – Himalayan Region

In the third climatic zone which starts from 9000 ft. (2700 m approx.) and extends to higher reaches of literal snow, last human habitation is at an altitude of about 15000 ft. (4500 m approx.). The climatic conditions keep on changing with the altitude, i.e., from 9000 ft. to 11000 ft. (2700-3300 m approx.) there is rain falls as well as snow fall, but after 11000 ft. (3300 m approx.) there is only snow fall. Habitants of this area who had never experienced rains in their living memory are now witnessing rain fall which is a new phenomena in the area. This is due to emission of hydro-carbons from fossil fuel driven vehicles layer of atmosphere, altering the temperature. Flora in this region consists of Bitula Chilgosa and at higher altitude Willows which also give way to alpine pastures after 14000 ft. (4200 m approx.) Due to climatic conditions the development of vernacular architecture is based on construction techniques which are entirely different than any other region. The rocks keep on disintegrating due to vast temperature difference between day and night. The snow falls is also in powder form, due to winter temperature of minus zero reaching upto minus 32 degree in mid winter. The mode of construction used is rammed earth block for walls beaten earth for flooring and flat roof consisting earth layer over 6-7 layers of Bitula barks which are placed over wooden planks supported by wooden joists (Fig. 12). There is 0.10 m layer of

sand in between two layers of Bitula barks. To conserve energy the height of rooms are confined to 2.10 m and openings are very small. A technique of supporting 2 thick earthen wall over 0.075 m frame by using small size battens kept at right angle to each other in alternate layers is same thing peculiar to this region. In the high altitude cold desert areas of Spiti, flat roof consisting earth covering ever willow branches resting in wooden joists is an innovative method of constructing flat roof (Fig. 12a&12b). This technique has been evolved due to absence of any other material available for roofing.

Figure 12 Views showing building typology (a) Mud houses at Tabo, Kinnaur, (b) Dwelling at Spiti Valley

8. CONCLUSION

Above Figure shows the typical architectural elements observed in the dwellings of the settlement. All the construction work is done with the locally available 'Deodar' timber and stone materials as slate. Following figure will summarize the traditional construction method and process that provide thermally comfortable shelter to the occupants by giving due considerations to local climatic conditions. The Spiti an mud houses are best suited to this cold mountain desert. Houses in Spiti are a good example of the symbiotic relation of humans with their environment.

In the end it is concluded that the traditional and vernacular buildings are ecological sensitive, climate responsive designs. Any change in these designs should aim for human comfort and aesthetical needs and these sustainable designs help to save culture at the lowest possible ecological cost. The traditional construction method and process provides thermally comfortable shelter to the occupants by giving due considerations to local climatic conditions. Traditional construction techniques in hills are dictated by the climatic constraints and the availability of the materials. The most common building materials used is wood, stone and mud bricks. And now the places which got connected by motorable roads, certain new techniques have been evolved by using local materials for the construction of the buildings suiting to local climatic conditions. Any new development should respect the site and adhere to the local needs.

ACKNOWLEDGMENTS

A Special thanks to my husband ''Mr. Abhinesh Kumar'' My Parents, My In-Laws and all family members. I would like to take this opportunity to express my heartfelt in debtness to my project guided by Prof. (Dr.) Devendra Pratap Singh, Director, Amity School of Architecture.

In the course of gathering this material, interviewing the participants, and collecting the data, I had invaluable assistance from the Student of 3RD Year, Section "C", Amity School of

Architecture and Planning who volunteered with me the Site Visit of Spiti as a summer project as a physical exercise. Without them, the completion of this study would not have been possible. I thoroughly enjoyed each and every one of them and learned so much from their "exercise wisdom" that I can share with all of you, and with my own family in the years that follow. I thank all of my Faculty members for simultaneously encouraging, guiding, and supporting my research ideas and me. A special word of thanks also goes to my family for their continuous support and encouragement.

REFERENCES

[1] Indian Standard, Improving Earthquake Resistance of Earthen Buildings - Guidelines. IS 13827: 1993.Bureau of Indian Standards (BIS), New Delhi, October 1993 (reaffirmed 1998), 20 pp.

[2] Dhajji Dewari. Hicyilmaz, K., Bothara, J., and Stephenson, M. (2012). Report no. 146, World Housing Encyclopedia, Earthquake Engineering Research Institute, United States.

[3] Timber-reinforced Stone Masonry (Koti Banal Architecture) of Uttarakhand and Himachal Pradesh, Northern India. Rautela, P., Girish, J., Singh, Y., and Lang, D.H. (2009). Report no. 150, World Housing Encyclopedia, Earthquake Engineering Research Institute, United States.

[4] Indian Standard, Repair and Strengthening of Masonry Building - Guidelines. IS 13935: 2009. Bureau of Indian Standards (BIS), New Delhi.

[5] Physical features and socio-cultural background of spiti valley.

[6] AVEI Newsletter, Issue 28 - May 2016 © Auroville Earth Institute.

[7] Wood and Stone, the vernacular architecture of Himachal Pradesh by Jay Thakkar and Skye Morrison (text) and Ahtushi Deshpande (photos)

[8] Existing Tourism Infrastructure and Services in Lahaul Valley of Himachal Pradesh: A Case Study of Hotels / Guest Houses, Home Stays and Travel Agencies by Dr. Arvind kumar.

[9] Climate and Construction– An Impact Assessment by TARA and DA Research team.

[10] A Report on the Field Documentation of Rock Art sites in Spiti Valley Himachal Pradesh (Phase-I) (03-12 October, 2015) by Indira Gandhi National Centre for the Arts New Delhi.

[11] Geological Society of America Bulletin, March/April 2006.

[12] Aaqib Mir, Yasir Sofi, Waleed Qari and Prof Dr. A. R.Dar. Revival of Traditional Earthquake Resistant Technique in Kashmir Valley, Replacing Timber With Bamboo in Dhajji Dewari (Bracing System), Comparing Cost and Strength Aspects. *International Journal of Civil Engineering and Technology*, 4(6), 2013, pp.01–11.

[13] C.V. Subramanian, N. Ramachandran and S. Senthamil Kumar, Performance Evaluation of the Designed Solar Passive Architecture Incorporated Residence in Warm Humid Climate. *International Journal of Civil Engineering and Technology*, 7(6), 2016, pp.523–535.